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PHOSPHOROUS MANAGEMENT IN THE LAKE ERIE BASIN. LAKE ERIE WASTEW--ETC(U)
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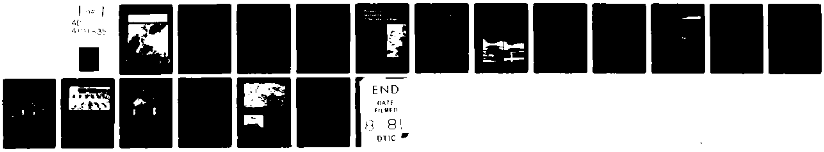

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WATER QUALITY INFORMATION BULLETIN

STEPHEN M. YAKSICH and RALPH R. RUMER, JR.

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Dr. Ralph Rumer served as a Consultant to the Lake Erie Wastewater Management Study Staff. He is a Professor of Civil Engineering at the State University of New York at Buffalo.

This report is an abbreviated account of an ongoing study being conducted by the U.S. Army Corps of Engineers with study headquarters at the district office in Buffalo, New York. The authority for the study is contained in Sections 108d and 108e of the Federal Pollution Control Act Amendments of 1972 (Public Law 92-500).

This study is aimed at developing a plan for managing phosphorus inputs into Lake Erie in order to restore the lake to a more desirable condition. Although still in progress, the findings and direction of the study have been established well enough so that a report can be made at this time.

Contents

About The Cover: *The cover photograph is a LANDSAT multispectral scanner band 4 image taken on May 10, 1975, of the western end of Lake Erie. The satellite orbits the Earth in an orbit 570 kilometers above its surface. Detroit and Lake St. Clair are at the top of the image and the bottom extends south of Findlay, Ohio. Band 4 is most sensitive to variations in the reflectance of water bodies and enhances variations in water sediment concentrations. Sediment plumes from a spring runoff event are apparent at the mouth of the Detroit, Maumee and Sandusky Rivers.*

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A101 835	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Phosphorus Management in the Lake Erie Basin - Lake Erie Wastewater Mangement Study		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Steven M. Yaksich, Ralph R. Rumer, Jr.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Engineer District, Buffalo, 1776 Niagara Street, Buffalo, New York 14207		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, Buffalo, 1776 Niagara Street, Buffalo, New York 14207		12. REPORT DATE 1978
		13. NUMBER OF PAGES 7
14. MONITORING AGENCY NAME & ADDRESS (If different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Phosphorus
Best Management Practices
Lake Erie

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The deteriorated condition of the Lake Erie water resource, which had been well publicized during the 1960's contributed to the decline in the fishing industry and prohibited the full recreational use of the lake. Lake Erie, like many similar lakes exposed to cultural changes in the drainage basins, was undergoing accelerated eutrophication. A eutrophic lake is characterized by high algal production, turbidity, and at times, low oxygen content. These conditions combine to cause unpleasant tastes and odors, nuisance weeds on surface waters and on beaches, and a general degradation of the lake's

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ecosystem which leads to less desireable fish species in the lake. This study has established some of the important cause and effect relationships that have contributed to this accelerated eutrophication. The major pollutant responsible for the eutrophication, or advanced aging of the lake, is the nutrient, phosphorus. A specific plan has been developed which will lead to significant improvement in the qualtiy of Lake Erie water and bring about a restoration of this vital fresh water resource. This managment plan addresses the cause and effect relationships between land use in the drainage basin and the level of phosphorus concentrations in the lake. The implication of the findings is that land management will be equally important as municipal and industrial wastewater renovation in the development of an overall plan for the reduction of phosphorus loadings to Lake Erie.

Phosphorus Management in the Lake Erie Basin

Highlights

The deteriorated condition of the Lake Erie water resource, which had been well publicized during the 1960's, contributed to the decline in the fishing industry and prohibited the full recreational use of the lake. Lake Erie, like many similar lakes exposed to cultural changes in their drainage basins, was undergoing accelerated eutrophication. A eutrophic lake is characterized by high algal production, turbidity, and at times, low oxygen content. These conditions combine to cause unpleasant tastes and odors, nuisance weeds on surface waters and on beaches, and a general degradation of the lake's ecosystem which leads to less desirable fish species in the lake. This study has established some of the important cause and effect relationships that have contributed to this accelerated eutrophication. The major pollutant responsible for the eutrophication, or advanced aging of the lake, is the nutrient, phosphorus. A specific plan has been developed which will lead to significant improvement in the quality of Lake Erie water and bring about a restoration of this vital fresh water resource. This management plan addresses the cause and effect relationships between land use in the drainage basin and the level of phosphorus concentrations in the lake. The implication of the findings is that land management will be equally important as municipal and industrial wastewater renovation in the development of an overall plan foı the reduction of phosphorus loadings to Lake Erie.

The objective of this publication is to summarize the findings and direction of the Lake Erie Wastewater Management Study being conducted by the U.S. Army Corps of Engineers. This report will be of interest to a broad spectrum of the public including water quality managers, land use managers, farmers, and soil conservationists.

Shore appearance is impaired with decayed Cladophora. High algae production caused by over enrichment of the lake with nutrients affects the quality and appearance of the water. This excessive plant growth leads to unpleasant tastes and odors, unsightly scum and weeds on surface water and beaches, and depletion of oxygen in the bottom waters of the lake where the dead plant material decomposes. Fisheries have been damaged and recreational use impaired.

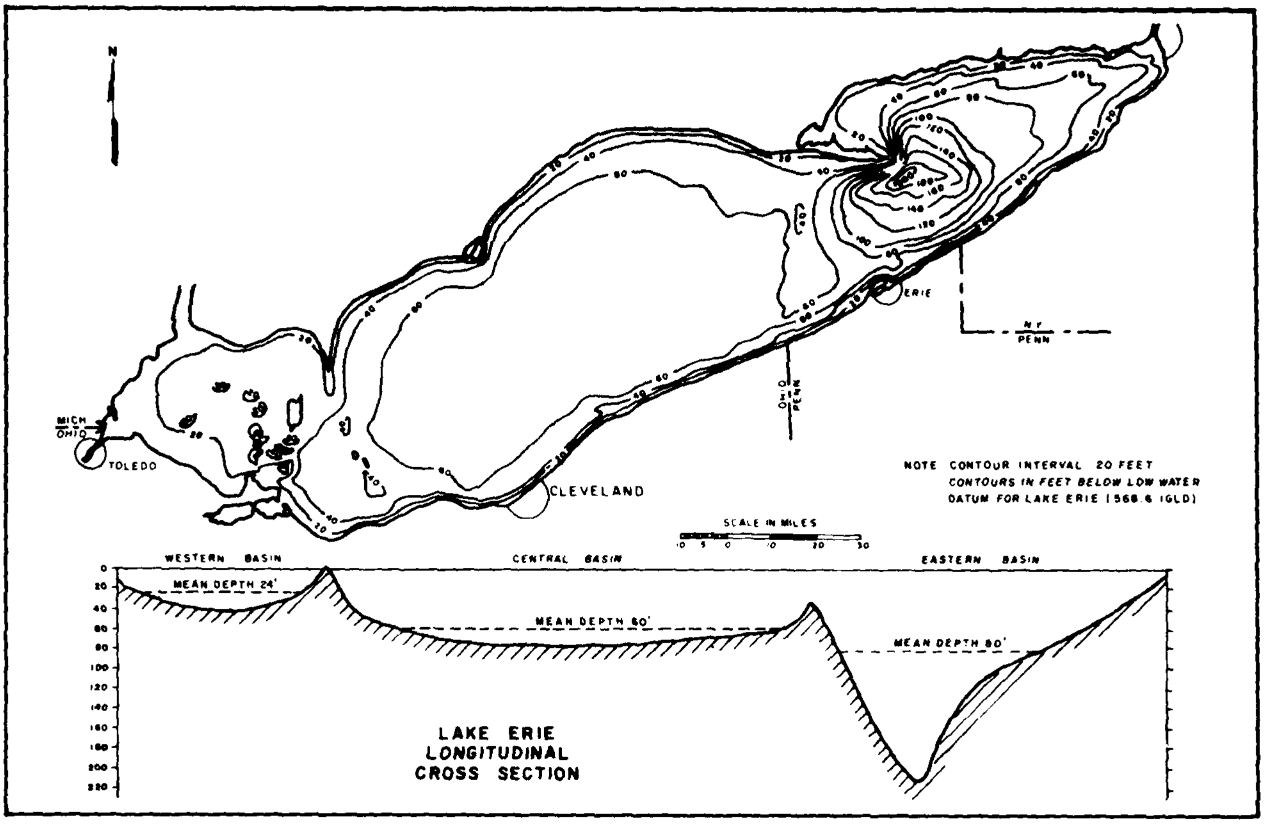


Figure 1. *This map depicts the bottom topography of Lake Erie. The Lake body itself is characterized as being comprised of three basins: Western, Central and Eastern.*

Lake Erie Drainage Basin

Description of the Physical System

Lake Erie is the southern-most of the Great Lakes. Approximately 20 percent of the water draining into Lake Erie originates within its own drainage basin. The other *80 percent* comes from the upper Great Lakes and enters Lake Erie by way of the Detroit River. Except for evaporation from the lake surface, 97 percent of the outflow from Lake Erie leaves by way of the Niagara River with the other 3 percent leaving by way of the Welland Canal. The Lake Erie drainage basin includes 10,000 square miles of land in Ontario, Canada and 20,000 square miles of land in the States of New York, Pennsylvania, Ohio, Indiana, and Michigan. The lake surface itself, occupies 10,000 square miles. The drainage basin is generally characterized by low, level, clay-rich land; however, the southeastern part of the basin is hilly and more rocky.

The shape of the lake body is such that it is frequently characterized as being comprised of three basins (Figure 1): the flat, shallow Western Basin (1200 square miles); the flat, but deeper, Central Basin (6,300 square miles); and the Eastern Basin (2,400 square miles), which has the steepest bottom gradients and greatest depth. A rocky island chain separates the shallow Western Basin (*mean depth* 24 feet) from the Central Basin (mean depth 60 feet) and a submerged sand and gravel ridge separates the Central Basin from the Eastern Basin (mean depth 80 feet).

Lake Erie is a vital resource serving millions of people. Its drainage basin is contained in two nations.

In comparison to the other Great Lakes, Lake Erie contains the smallest water volume while its drainage basin contains the largest population.

Because of its relatively small volume and the large population density, Lake Erie has experienced the greatest changes in water quality as a result of the intensity of man's activities within its drainage basin.

Land Use

The population living within the Lake Erie drainage basin has grown from about 2 million in 1878 to 14 million in 1979, with 1.5 million in the Canadian portion of the drainage basin. This growth has been accompanied by urbanization, industrialization, and intensified agricultural development. A large part of the land surface has been deforested to accommodate the development of these activities. Most of the waste products generated by activities in the drainage basin ultimately enter Lake Erie (unless removed by some wastewater treatment process).

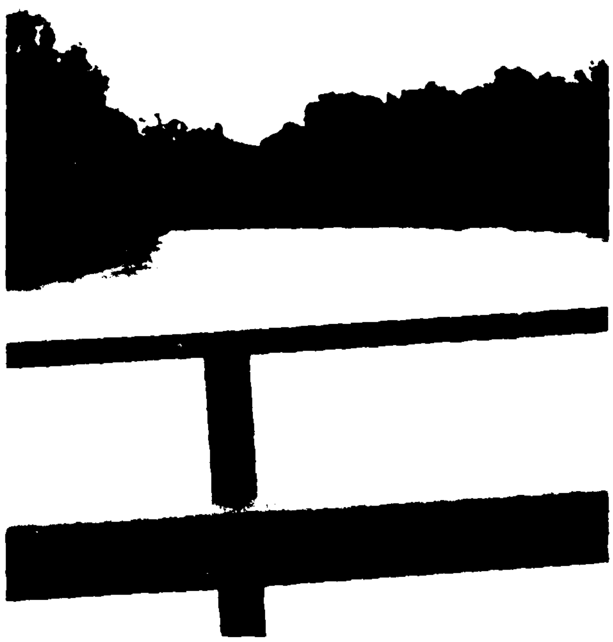
Since the treatment of wastewater has traditionally required collection and processing at a specific site, the pollutant load contained in the effluents from wastewater treatment facilities are referred to as point sources. Municipal and industrial wastewater treatment facilities are normally located adjacent to a receiving waterbody which provides dilution and conveys the unremoved substances downstream. On the other hand, the pollutant load carried by surface runoff is widely distributed throughout the drainage basin and it is generally not feasible to process this water. The pollutant substances conveyed by surface runoff are termed diffuse source loadings when they enter receiving waterbodies. The collection and transport of pollutant substances by water flows occur then in two principal ways. The first involves sewage systems (i.e. sewer networks and wastewater treatment facilities) and are termed point source loads where the treated wastewater is discharged to the stream or lake. The second involves the natural process of rainfall runoff (or snowmelt) and pollutants carried by this runoff flow are termed diffuse source loads because of the nature in which they enter the streams and rivers which comprise the drainage system to Lake Erie.

Pollutants enter Lake Erie through direct discharge from sewage collection systems (point sources) and from land runoff and tributary inflows (diffuse sources).

Point sources result from man's use of water. Diffuse sources result from man's use of land.

Low water flow in Sandusky River

High water flow in Sandusky River



The concentration of total phosphorus in a stream varies greatly with its rate of flow. Stream sampling data indicated increased phosphorus concentrations occurred during and immediately following rains or snow melt when the stream contained high runoff. These streams must be sampled during these high flow events in order to obtain reliable phosphorus loading estimates.

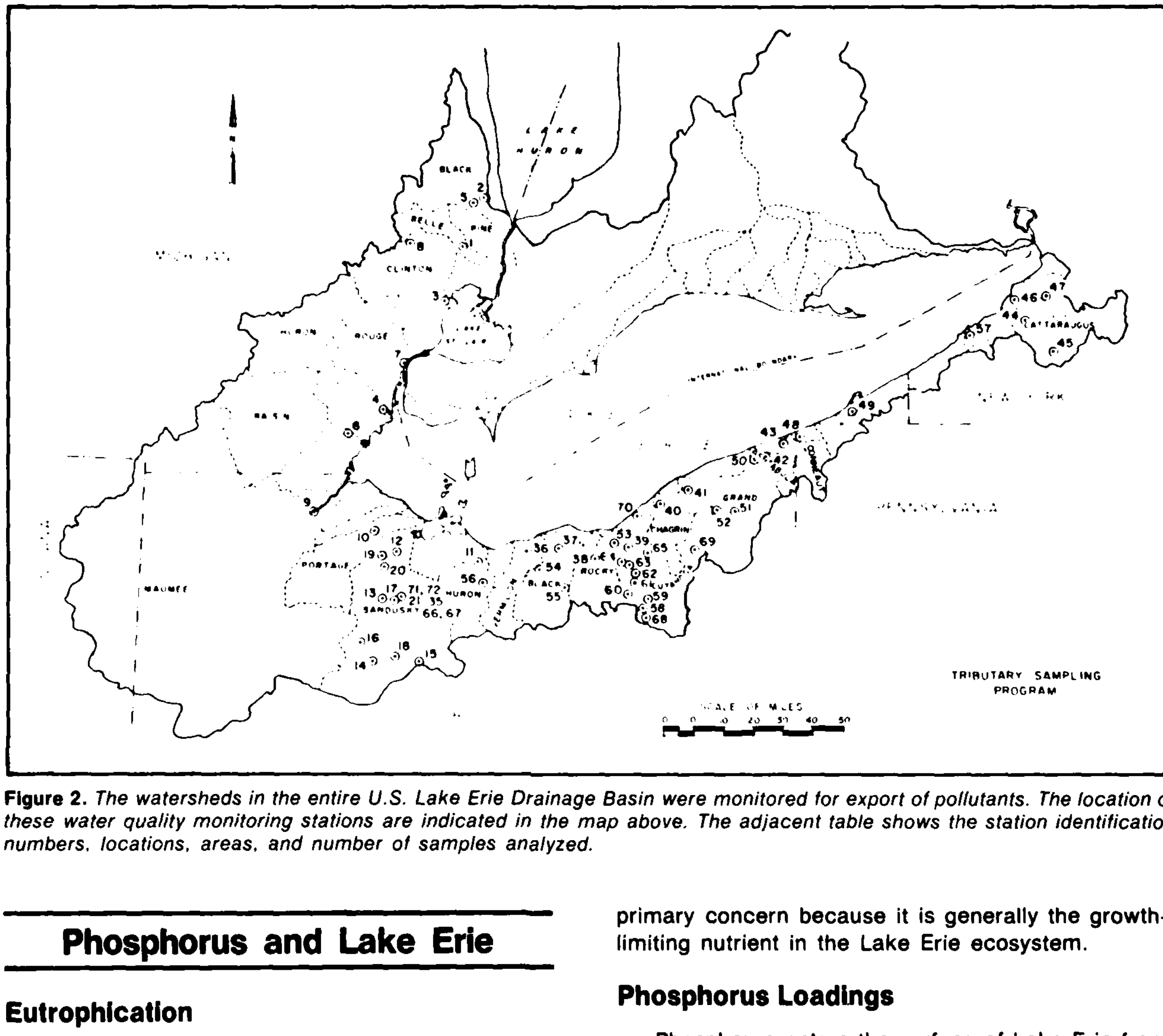


Figure 2. *The watersheds in the entire U.S. Lake Erie Drainage Basin were monitored for export of pollutants. The location of these water quality monitoring stations are indicated in the map above. The adjacent table shows the station identification numbers, locations, areas, and number of samples analyzed.*

Phosphorus and Lake Erie

Eutrophication

Lake Erie, which is undergoing cultural eutrophication, has been subject to increased nutrient loadings as a result of man's activities in the drainage basin. The resulting higher levels of nutrients in the lake stimulate excessive phytoplankton growth. Since phytoplankton form the first level of the food chain in a lake ecosystem, the overall biological productivity of the lake is affected. Phosphorus is of primary concern because it is generally the growth-limiting nutrient in the Lake Erie ecosystem.

> *Lake Erie has undergone cultural eutrophication, which is an enrichment of nutrients, particularly phosphorus, as a result of man's activities.*
>
> *Improving the quality of water in Lake Erie will require management of the level of phosphorus contained in the lake waters.*

Phosphorus Loadings

Phosphorus enters the surface of Lake Erie from the atmosphere, at the lake boundaries from shoreline erosion of phosphorus-bearing sediments, in the tributary inflows that drain the watershed, and in the direct discharges from wastewater outfalls. In order to obtain improved estimates of phosphorus loadings to Lake Erie, a program of water quality sampling was begun in December 1974 and continued until September 1977. The late winter and early spring were intensively sampled because of the high runoff that occurs during this period. Sampling stations first were established on 10 tributaries in Ohio and New York. Approximately one-third of the Lake Erie drainage basin was accounted for by sampling at the selected stations. In addition, sampling of the Detroit River inflow was carried out in conjunction with the Detroit District, Corps of Engineers. Later the number of tributary stations was increased to 72 (Figure 2).

Water Quality Monitoring Stations in the Lake Erie Drainage Basin.

Stream	Station Number	Sampling Site	Drainage Area (sq. mi.)	Map Code	No. of Samples Analyzed
Belle	04160600 (1)	Memphis, MI	151	1	60
Black	04159500 (1)	Fargo, MI	480	2	61
Clinton	04165500 (1)	Mt. Clemens, MI	734	3	63
Huron	821114 (2)	S. Metropolitan Pkwy., MI	849	4	50
Mill Creek	04159900 (1)	Avoca, MI	169	5	65
Raisin	04176500 (1)	Monroe, MI	1,042	6	61
Rouge	820070 (2)	W. Jefferson Bridge, MI	467	7	57
Sashabaw Creek	04160800 (1)	Drayton Plains, MI	20.9	8	62
Maumee	04193500 (1)	Waterville, OH	6,330	9	1,411
Portage	04195500 (1)	Woodville, OH	428	10	1,292
Huron	04199000 (1)	Milan, OH	371	11	1,543
Sandusky	04198000 (1)	Fremont, OH	1,251	12	1,283
Sandusky	04197000 (1)	Mexico, OH	774	13	908
Sandusky	04196500 (1)	Upper Sandusky, OH	298	14	1,139
Sandusky	04196000 (1)	Bucyrus, OH	88.8	15	1,180
Tymochtee Creek	04196800 (1)	Crawford, OH	229	16	973
Honey Creek	04197100 (1)	Melmore, OH	149	17	1,194
Broken Sword	04196200 (1)	Nevada, OH	83.8	18	988
Wolf Creek West Branch	04197300 (1)	Bettsville, OH	66.2	19	930
Wolf Creek East Branch	04197450 (1)	Bettsville, OH	82.3	20	929
Mohawk Lake	A (3)	Tributary below Mohawk Lake	5.3	21	22
Honey Creek	1 (3)	At Route 231	171	22	43
Buckeye Creek	E (3)	At Route 67	5.6	23	34
Honey Creek	3 (3)	Upstm. from Silver Creek	121.6	24	34
Silver Creek	4 (3)	Confluence with Honey Cr.	24.4	25	35
Silver Creek	M (3)	Downstream from Marsh	16.4	26	43
Silver Creek	N (3)	Upstm. from Marsh	12.1	27	43
Aichholz Ditch	6 (3)	Honey Creek, County Rd. 49	16.3	28	32
Honey Creek	5 (3)	Upstm. from Aichholz Ditch	95.6	29	42
Honey Creek	7 (3)	Attica, Route 4	75.6	30	41
Honey Creek	F (3)	Weis Road	10.1	31	33
Honey Creek	8 (3)	Upstm. from Brokenknife	26.8	32	31
Brokenknife Cr.	D or 9 (3)	County Line Road	20.5	33	35
Trib. Honey Cr.	B (3)	R.R. North at Scott Rd.	3.4	34	29
Honey Creek	10 (3)	Rt. 103	15.7	35	34
Vermilion	04199500 (1)	Vermilion, OH	262	36	106
Black River	04200500 (1)	Elyria, OH	396	37	101
Rocky	04201500 (1)	Berea, OH	267	38	60
Cuyahoga	04208000 (1)	Independence, OH	707	39	441
Chagrin	04209000 (1)	Willoughby, OH	246	40	101
Grand	04212200 (1)	Painesville, OH	701	41	63
Ashtabula River	04212500 (1)	Ashtabula, OH	121	42	23
Conneaut Creek	04213000 (1)	Conneaut, OH	175	43	23
Cattaraugus Creek	04213500 (1)	Gowanda, NY	432	44	142
S. Br. Cattaraugus	04213490 (1)	Otto, NY	25.60	45	77
Delaware Creek	04214040 (1)	Angola, NY	8.15	46	77
18 Mile Creek	04214200 (1)	N. Boston, NY	37.20	47	77
Raccoon Creek	04213040 (1)	W. Springfield, PA	2.53	48	54
Mill Creek	04213200 (1)	Erie, PA	9.16	49	53
Hubbard Run	04212600 (1)	Ashtabula, OH	.88	50	38
Hoskins Creek	04210100 (1)	Hartsgrove, OH	5.42	51	40
Montville Ditch	04210090 (1)	Montville, OH	.29	52	40
Big Creek	04208502 (1)	Cleveland, OH	35.3	53	60
Plum Creek	04200100 (1)	Oberlin, OH	4.83	54	64
Neff Run	04199800 (1)	Litchfield, OH	.76	55	60
Norwalk Creek	04198100 (1)	Norwalk, OH	4.92	56	60
Canadaway		Fredonia, NY	34.9	57	36
Cuyahoga River	04206000 (1)	Old Portage, OH	404	58	197
Mud Brook	04206050 (1)	Akron, OH	29.3	59	162
Yellow Creek	04206220 (1)	Botzum, OH	30.7	60	177
Furnace Run	04206370 (1)	Everett, OH	17.7	61	162
Cuyahoga River	04206400 (1)	Peninsula, OH	494	62	353
Brandywine Creek	04206420 (1)	Jaite, OH	27.2	63	176
Chippewa Creek	04206450 (1)	Brecksville, OH	17.7	64	154
Tinkers Creek	04207200 (1)	Bedford, OH	83.9	65	313
Ackerman Ditch	G (3)	Ackerman Ditch	4.4	66	32
Mohawk Lake	AA (3)	Tributary above Mohawk	3.72	67	34
Little Cuyahoga R.	04205700 (1)	Akron, OH	59.2	68	24
Cuyahoga River	04202000 (1)	Hiram Rapids, OH	151	69	39
Euclid Creek	04208690 (1)	Euclid, OH	22.6	70	189
Rock Creek West	RWW (4)	County Rd 16	13.6	71	34
Rock Creek East	RCE (4)	County Rd 16	7.0	72	33

(1) U.S. Geological Survey Station Code
(2) Michigan Department of Natural Resources Code
(3) Corps of Engineers Honey Creek Watershed Code
(4) Corps of Engineers Code

The results of this sampling program provided greatly improved estimates of the phosphorus loading to Lake Erie. It was discovered that phosphorus concentrations increased with increasing stream flows which demonstrated that diffuse source loading of phosphorus increased during high rainfall/runoff periods. In contrast, the point source loadings of phosphorus were found to be relatively constant loads with no dependence on streamflow. It was also determined that much of the phosphorus being transported to Lake Erie by its tributaries was attached to sediments that had been eroded from the land surface or resuspended from the river bottom.

Based on correlations between streamflow and phosphorus concentrations, a methodology was developed and calibrated for obtaining estimates of diffuse source phosphorus loads for both the sampled areas and the unsampled areas of the Lake Erie drainage basin. Estimates of the point source loadings were based on an analysis of treatment plant records. Atmospheric loadings were estimated from data extrapolated from measurements taken within the Great Lakes Basin. Phosphorus contained in shoreline eroded materials was excluded because it was not considered available for biological uptake. The detailed estimates for each tributary and for different runoff periods were compiled and used in obtaining estimates of the annual loading of total phosphorus for each year, 1974 to 1977. Utilizing long-term hydrologic runoff records, so-called "base year" estimates of total phosphorus loading to Lake Erie were then developed. These "base year" estimates were subsequently used in the development of phosphorus loading reduction programs.

The bulk of phosphorus from diffuse sources and inland point sources reaches Lake Erie in association with suspended sediment transported during storm events.

The biological availability of sediment-bound phosphorus varies considerably with flow and between river basins. This fraction ranges from 43 to 89 percent.

Base Year Estimates of Total Phosphorus Loads to Lake Erie:

Western Basin — 14,499 metric tons per year.
Central Basin — 4,007 metric tons per year.
Eastern Basin — 1,463 metric tons per year.
Whole Lake Total — 19,969 metric tons per year.

Although there is uncertainty as to what proportion of the total phosphorus delivered each year to Lake Erie will become available to biological uptake, there is certainty that the phosphorus attached to sediments carried by Lake Erie tributaries can be utilized by algae. Therefore, reduction in the erosion of sediment will decrease the amount of phosphorus available to algae in Lake Erie.

Soil erosion is one cause of agricultural pollution. Phosphorus carrying soil particles become detached from the field surface from raindrop impact. These particles are then transported to the lake by surface runoff. Raindrop impact and surface runoff can be effectively reduced by implementation of alternative land management practices.

Phosphorus Load Reduction

There is program underway in the Great Lakes Basin to reduce the phosphorus loadings from point sources. This is being achieved by adding phosphorus removal processes to existing wastewater treatment plants or incorporating these processes in newly constructed wastewater treatment plants. It is expected that this program will reduce the concentration of total phosphorus in the effluents from these plants to between 0.5 mg/l to 1 mg/l. Dependir g on the actual effluent concentrations of total phosphorus, the loadings of total phosphorus to Lake Erie will be reduced accordingly to between 14,200 to 15,500 metric tons per year.

The expected reduction in phosphorus loading as a result of the control of phosphorus concentrations in the effluents from wastewater treatment plants (point sources) will not be sufficient to reach the 11,000 metric tons per year total phosphorus loading objective for Lake Erie. This objective is set in the Great Lakes Water Quality Agreement of 1978. It is projected that this objective loading of 11,000 metric tons per year of total phosphorus will bring about the desired increase in the summertime levels of dissolved oxygen in the bottom waters of Lake Erie, which in turn, will lead to a rejuvenation of the desired fish species. Utilizing long-term phosphorus budget models that incorporate the loadings of phosphorus, the outflow of phosphorus from the lake via the Niagara River and the exchange and retention of phosphorus with the lake sediments, the effect of the loading objective on in-lake phosphorus concentrations (Figure 3) and the trophic status of the lake (Figure 4) have been estimated.

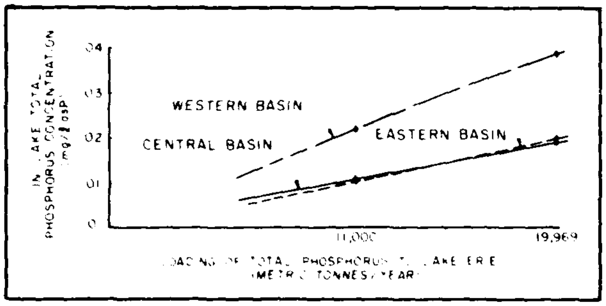


Figure 3. *The application of the long-term phosphorus budget model projects the following reductions for in-lake concentrations of total phosphorus that would result if the objective loading of 11,000 metric tons were achieved.*

The above findings and projections have focused attention on the need to develop plans that will bring about a reduction in diffuse source loadings of total phosphorus so that the loading objective of 11,000 metric tons of total phosphorus can be achieved. Since the diffuse source phosphorus load emanates from the rainfall-runoff process and the erosion and transport of phosphorus-bearing sediments, the control of diffuse sources will require land management

> *The Great Lakes Water Quality Agreement of 1978 set a total phosphorus loading objective of 11,000 metric tons per year for Lake Erie.*
>
> *Control of diffuse sources of phosphorus as well as point sources in the Lake Erie basin, will be required to reach this objective.*

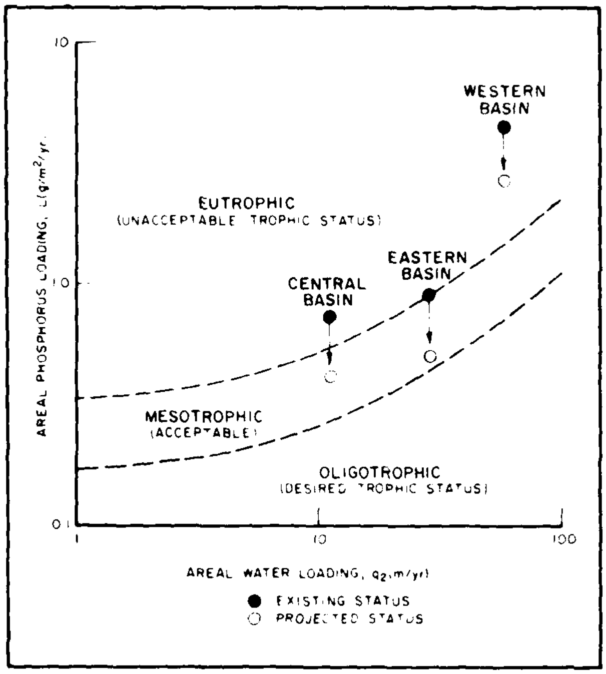


Figure 4. *This trophic status graph reflects the expected improvement in the trophic status of the three basins in Lake Erie if the total phosphorus load of 11,000 metric tons is achieved.*

techniques to keep the soil on the land. Because of the large variations in annual runoff volume and the seasonal distribution of surface runoff, the quantity of diffuse source loading also varies considerably from year to year. It is, therefore, not possible to state the exact percentage of reduction in diffuse source loading in any given year that will be required to achieve the objective total loading of 11,000 metric tons. However, it is still important that diffuse source phosphorus loads to Lake Erie be reduced.

Control of Diffuse Source Loading of Phosphorus

Erosion and Transport Process

The common factor in the generation of diffuse source loading is the rainfall-runoff event. The physical transport process begins with the initial material detachment from the earth's surface resulting from the impact of the raindrop and the erosive transport during surface runoff. In this way, both dissolved phosphorus and particulate phosphorus are moved towards Lake Erie by the drainage network. Diffuse source particulate phosphorus is transported incrementally downstream towards Lake Erie by each

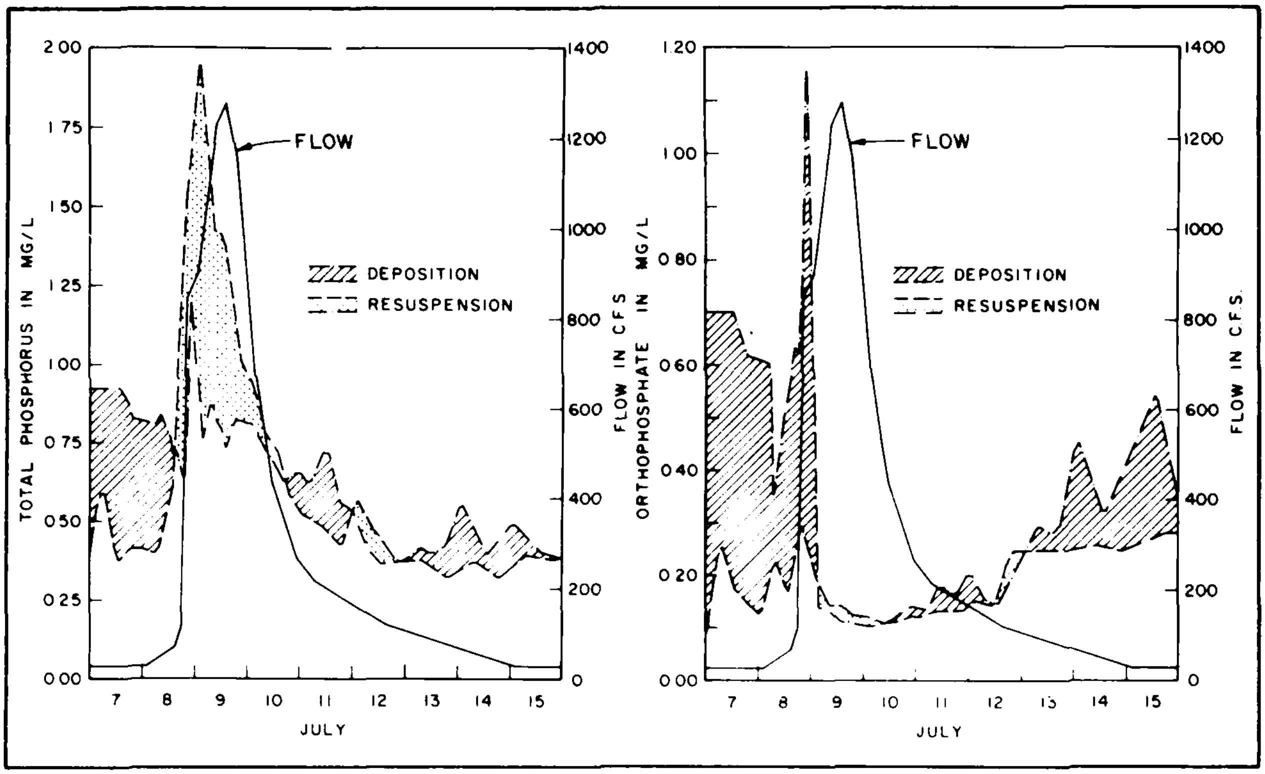


Figure 6. *In-stream processing of phosphorus. The above graphs show deposition and resuspension of (a) total phosphorus and (b) orthophosphate in the Sandusky River near Upper Sandusky — Storm beginning 7 July 1976. Both total phosphorus and soluable orthosphosphate are lost from the water during low flow. Only total phosphorus is resuspended during high flow. As a result, soluble orthophosphate from point sources reaches the lake in a particulate form.*

rainfall-runoff event (Figure 5). Large runoff events are the most significant in terms of moving phosphorus ever closer to Lake Erie.

Deposition and resuspension of sediments were calculated utilizing a dynamic river phosphorus transport model. Based on field studies in the Sandusky River and the application of the river transport model, it was found during steady flow conditions that phosphorus discharged into the river from a point source was rapidly removed from the water column by adsorption onto river sediments and microorganisms. This deposited phosphorus is resuspended during high flow events and transported downstream. The findings clearly showed that orthophosphate is neither deposited nor released from sediments during high flow events. However, during low flows, both total phosphorus and orthophosphate were lost from the water column. Thus, the river transport of phosphorus acts to convert orthophosphate, which is readily available for biological uptake, to total phosphorus, which is only potentially available to biological uptake (Figure 6).

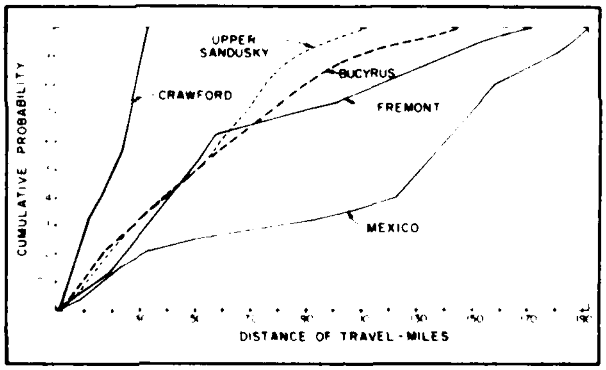


Figure 5. *Cumulative probability that total phosphorus will be deposited in-stream before traveling the stated distance. Sandusky River Basin, 12 July 1974.*

While some of the sediment phosphorus is directly delivered to the lake, a substantial portion reaches the lake through a series of desposition and resuspension events.

Phosphorus from point sources is lost from the water column to the river sediments.

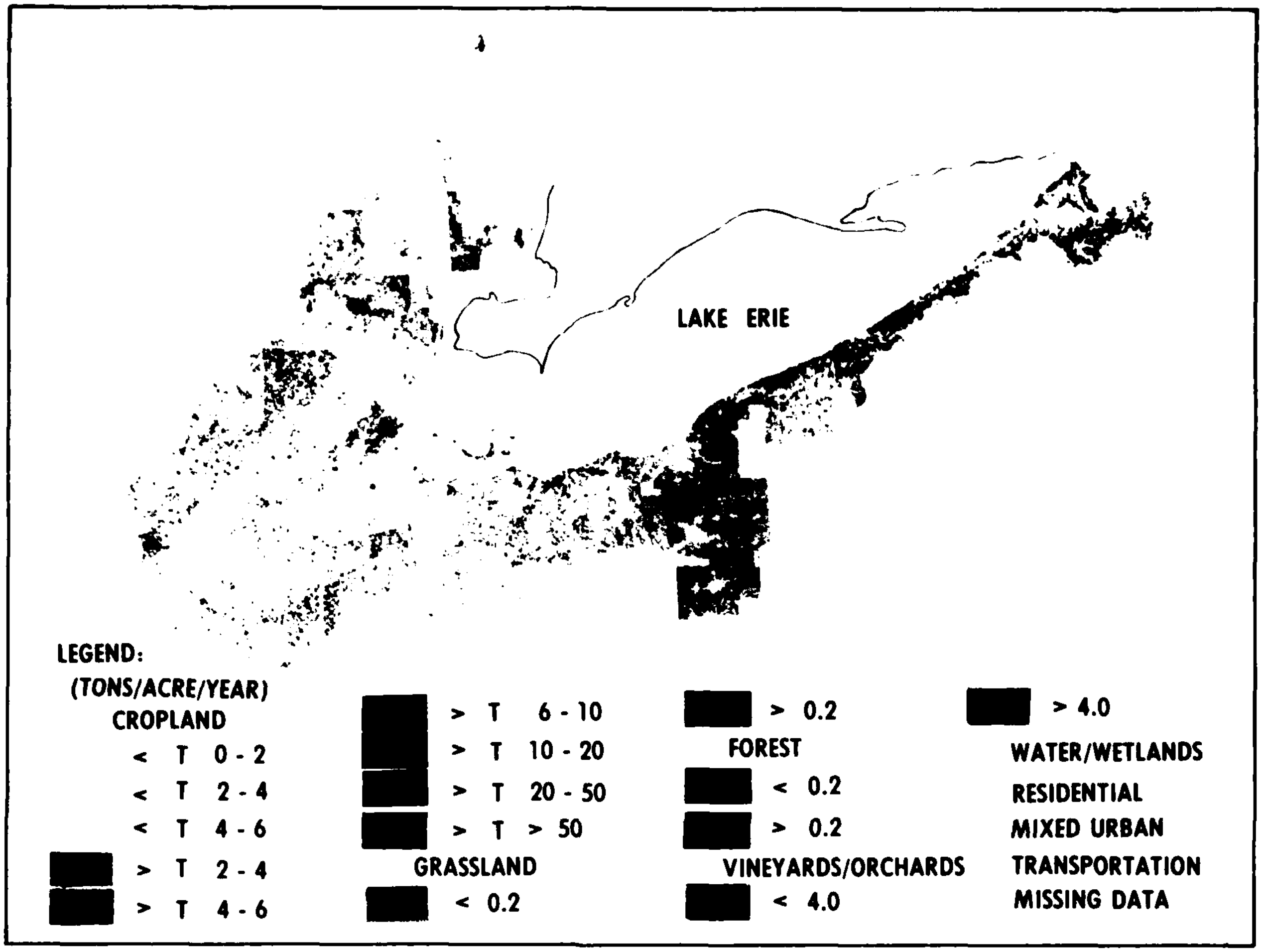


Figure 7. *Potential Gross Erosion in the United States Drainage of Lake Erie. T is the soil loss tolerance factor or that level of soil loss at which the productivity of the soil can still be maintained.*

Diffuse Sources

Although there is a naturally occurring background level of phosphorus that will be transported by river flows, the application of fertilizers and other phosphorus-bearing substances to the soil surface and the subsequent erosion of the soil particles, has led to an unmistakable increase in the quantity of phosphorus contained in the tributaries draining to Lake Erie. The findings of this study have demonstrated that about one-half of the total phosphorus loading originating from the Lake Erie drainage basin comes from diffuse sources. In the Maumee River Basin, approximately 80 percent of the total phosphorus loading discharged to Lake Erie originates from diffuse sources. In some other areas of the U.S. Lake Erie drainage basin, diffuse sources make up only a small fraction of the total loading.

Diffuse souce-loading of phosphorus is not amenable to treatment in the usual sense of the word. The only practicable approaches toward reducing diffuse source loading are reduction in the application of phosphorus to the land surface and/or reduction in the quantity of phosphorus being transported to Lake Erie by the rainfall-runoff process. Although the first approach has merit, its impact will be small and any major reduction will result from controlling erosion. Therefore, this study has focused on devising control measures which either prevent of reduce the amount of phosphorus leaving the initial application site.

Reducing gross erosion will reduce phosphorus loads to Lake Erie.

Evaluation of Diffuse Sources

Because of the very significant correlation between phosphorus transport and sediment as a carrier of phosphorus, land use and land resource characteristics in the Lake Erie drainage basin were

No-till planting methods are designed to reduce soil erosion and prevent nutrient displacement by minimizing disturbance to soil structure. Lower farm fuel and labor cost are realized. Soil tilth, drainage, and moisture retention are improved.

inventoried, particularly with regard to potential for gross erosion and potential for erosion control. This identification process reduced the land area to be considered in terms of active contribution of phosphorus to Lake Erie. An important part of this identification process involved the development of a Land Resources Information System (LRIS) for the U.S. portion of the Lake Erie drainage basin. The LRIS contains data on existing land use and soil type referenced according to geographical and political position in the drainage basin. This information was computerized for quick and easy use.

Utilizing aerial photographs obtained from special photographic missions, land use was coded on a square grid with four and nine hectare grid areas for intensive study and 16 and 36 hectare grid areas for less intensive study. (One hectare equals 2.47 acres). The soils of the basin were coded into LRIS using available data from each county.

Utilizing accepted methods for estimating gross soil erosion potential and the LRIS, the Lake Erie drainage basin was analyzed to explore opportunities for erosion control (Figure 7). In this way, it was possible to examine the effects that various land management practices might have on reducing the amount of land-generated phosphorus loadings to Lake Erie. These various practices had to be considered in the context of their economic and technical suitability as well as their relative effectiveness in reducing sediment and phosphorus loadings to Lake Erie. The Best Management Practices (BMP) that were established for the Lake Erie drainage basin in terms of their effectiveness in reducing sediment erosion and phosphorus transport includes only those practices which will reduce gross erosion and sediment/phosphorus delivery to the greatest degree at the least cost to the public and the agricultural community.

Diffuse source phosphorus is derived principally from agricultural land use, particularly crop production.

Best Management Practices

The best management practices that will reduce potential gross erosion deal largely with the agricultural community. This is to be expected because here is where regular applications of phosphorus take place and new soil is exposed annually. It has been determined that conservation tillage and no-till planting methods have the potential of decreasing total phosphorus loadings to Lake Erie by some 2,000 to 5,000 metric tons per year. This

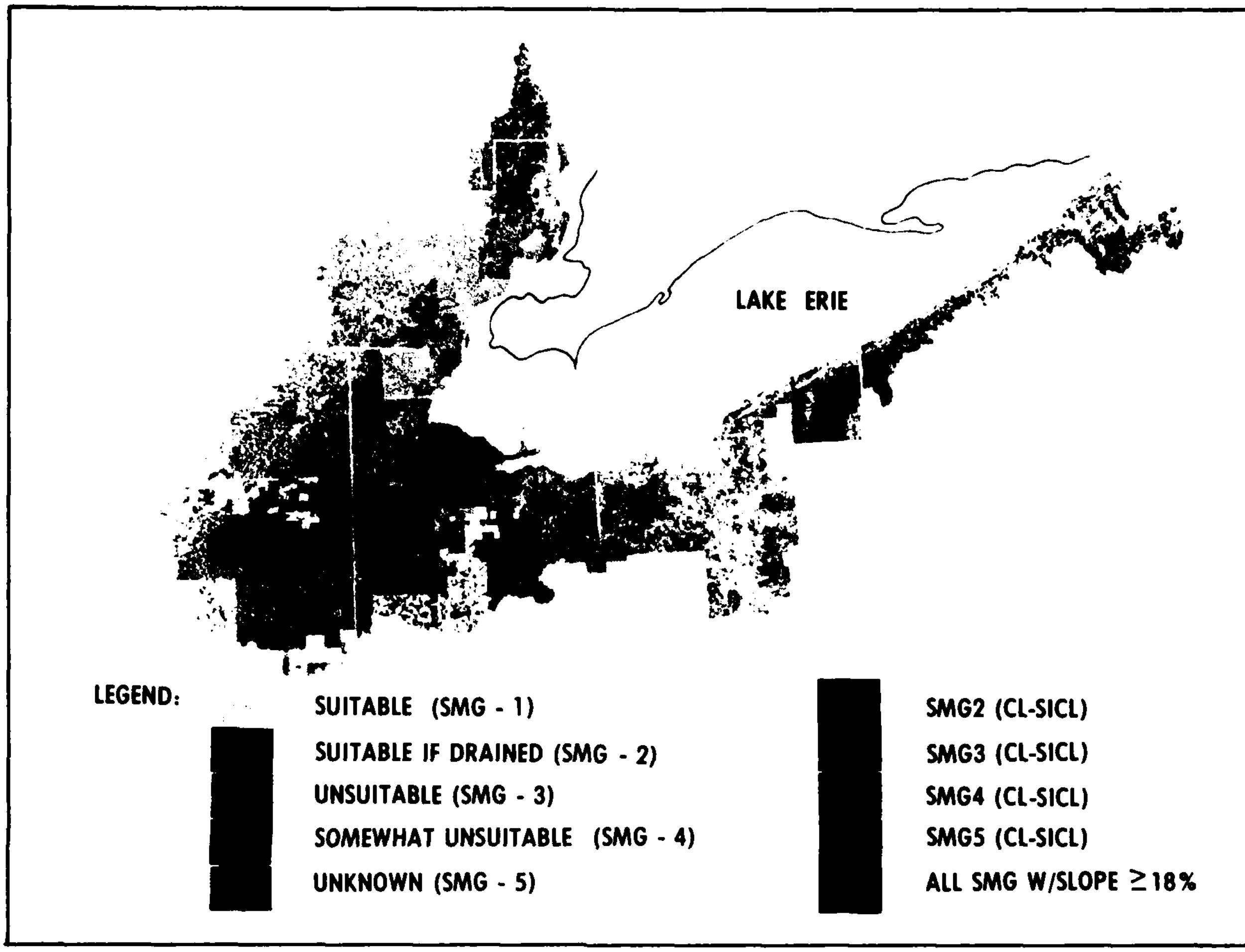


Figure 8. *Suitability of Soils in the United States Drainage of Lake Erie for Reduced Tillage: Soil Management Groups.*

range of phosphorus loading reduction has the potential of achieving the diffuse source phosphorus loading reductions required to meet the phosphorus loading objective for Lake Erie of 11,000 metric tons per year.

Conservation tillage and no-till planting methods help to keep soil and nutrients in place. However, the degree to which these methods can be instituted depends on the particular soil drainage characteristics. The LRIS was utilized to establish the areas in the Lake Erie drainage basin best suited to reduced tillage planting methods (Figure 8). For instance, in the drainage basin tributary to the Western Basin of Lake Erie, conservation tillage and no-till planting methods could bring about up to 70 percent reduction in potential gross erosion. In the Central Basin, the projections indicate a possible 65 percent reduction. Although the Eastern Basin does not make a significant contribution to the total phosphorus loading to Lake Erie, conservation tillage and no-till planting methods could bring about up to 50 percent reduction in potential gross erosion in that basin. Overall, there is a high probability that the objective loading of 11,000 metric tons per year can be attained through the point source phosphorus removal programs now underway and the implementation of conservation tillage and no-till planting methods

A rural diffuse source total phosphorus loading reduction of 2,000 to 5,000 metric tons per year is possible. It will depend on the extent to which conservation tillage and no-till practices are adopted in the Lake Erie basin.

An educational and technical assistance program is needed to accelerate the adoption of conservation tillage, no-till, and other cost effective best management practices.

The environmental benefits of erosion control extend well beyond a reduction in phosphorus.

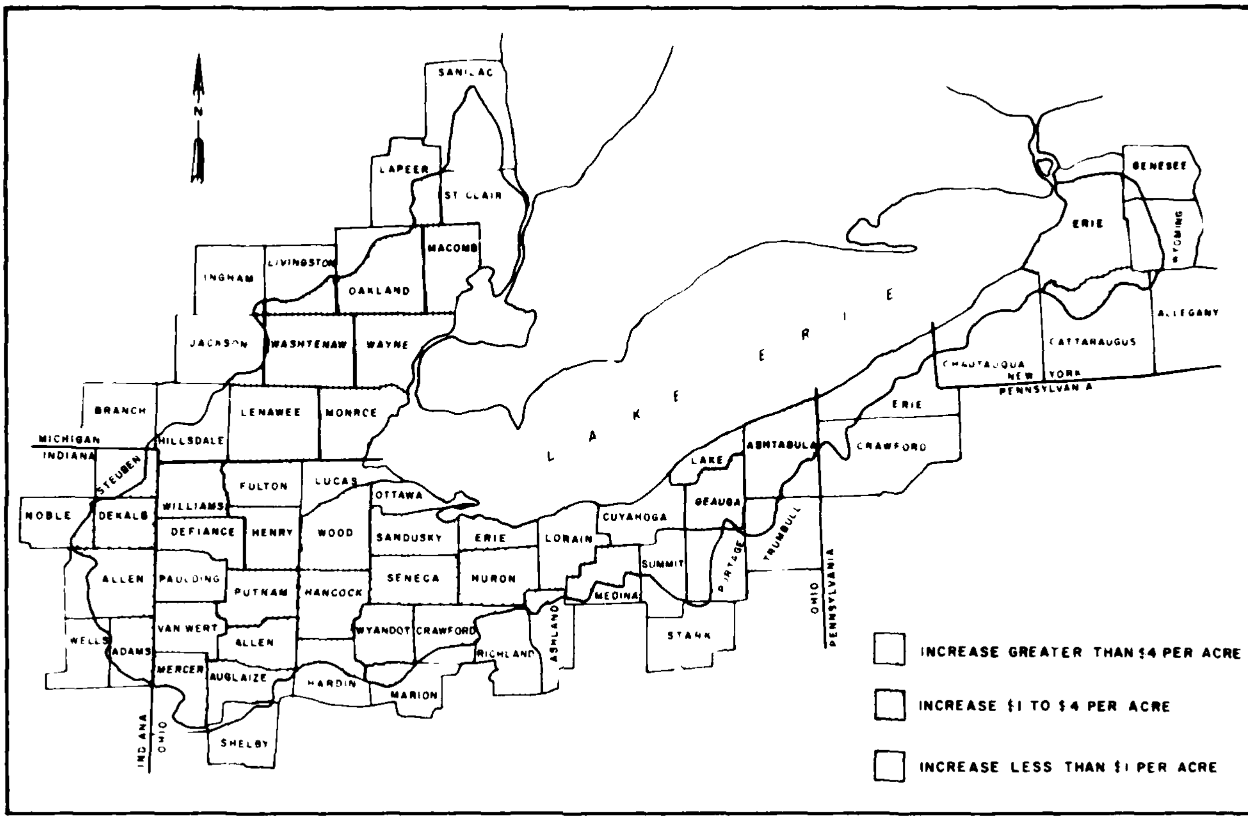


Figure 9. *This map shows change in County net farm income with adoption of reduced tillage on suitable soils. The farmers experiencing the most economic gain are in the western portion of the basin.*

which will lead to the control of diffuse source loadings of phosphorus.

Economic Impact

An analysis of the economic impact that might result from the implementation of conservation tillage and no-till planting methods indicated that there would be an increase in net farm income for the selected plans (Figure 9). However, economic incentive in the form of cost sharing will be required to make the initial change.

> *Adoption of reduced tillage appears to be an economically feasible method of reducing erosion in the Lake Erie Basin.*

Implementation

The task of implementing and monitoring a diffuse source phosphorus control plan in the Lake Erie Basin is not as straight forward as the task of controlling point sources of phosphorus. It is logical to look to the agencies, organizations, and institutions with authority, experience, and capabilities in agricultural runoff and erosion control. Therefore, the local Soil and Water Conservation Districts (SWCD) are the most likely institutions to address the management of diffuse sources of phosphorus. These special-purpose districts exist within each county of the Lake Erie drainage basin. The record of involvement and cooperation of SWCD's with the agricultural community and other governmental agencies has been strong and this strength will be important in the development of a diffuse source phosphorus reduction program. However, additional educational assistance, financial support, and increased technical staffing will be necessary for SWCD's to take on this added responsibility. Agencies such as the

> *Criteria for setting priorities for treatment of critical areas will include potential soil loss, phosphorus availability of eroded soil, and cost effectiveness of reduced tillage systems and other applicable best management practices. Land parcels will have to be reviewed with these criteria in mind.*

No-till planting permits crop residue or winter cover protection during the erosion-sensitive winter and spring months.

Cooperative Extension Service and the Soil Conservation Service can provide educational and technical support to the SWCD's providing they, and other cooperating agencies, obtain adequate funding and staffing.

Soil and nutrients are kept in place using reduced tillage planting methods. Clear water from a field using reduced tillage flows into a stream conveying a high suspended sediment load from a conventionally tilled field.

Other Lake Erie basin-wide benefits will result if the diffuse source management plan for phosphorus control is successfully implemented. There will be less sediment delivered at the mouths of tributaries and dredging costs will be reduced in Lake Erie Harbors. Treatment costs for sediment removal from domestic water supplies will be reduced, other sediment-attached pollutants will be prevented from entering Lake Erie, and fishery resources will be enhanced in the rivers and streams of the Lake Erie drainage basin because of reduced in-stream sedimentation.

It is recommended that a demonstration program be implemented in a specific watershed in the Lake Erie drainage basin. The results of the adoption of conservation tillage and no-till practices will be assessed in order to determine the applicability of these practices to other areas in the drainage basin in terms of reducing phosphorus loading to Lake Erie.

The final phase of this study will outline the wastewater management program which will lead to an improvement of in-lake water quality and the rehabilitation of Lake Erie.

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March 1980